APPENDIX A

HOT-MIX BITUMINOUS PAVEMENTS, DESIGN AND CONTROL

AI. General.

Al-1. Procedures and criteria. Procedures and criteria in this appendix apply to design and control of hot-mix bituminous pavements using penetration grades of asphalt cement, tar cement, or rubberized tar.

Al-2. Alternative approaches. It is anticipated that under mobilization conditions, bituminous pavement materials will be supplied by established local sources. In most cases these sources have been utilized by Federal or state agencies in the past and have approved design mixes available to meet the needs as outlined in this manual. Review of the available mix results along with the associated material test results and supplemented by field inspections and testing of present materials should supply sufficient information to proceed with design and construction.

Al-3. Design requirements. The following discussion is presented to provide the designer with design requirements as an aid to evaluating available materials and to provide information on methods of obtaining design data if not locally available.

A2. Design.

A2-1. Survey of materials. A survey of materials available in suitable quantities for use in construction of the pavement is the first step in the design of a paving mixture. Materials normally required for the paving mixture are coarse aggregate, fine aggregate, mineral filler, and bitumen.

A2-2. Sampling. Sufficient quantities of materials are to be obtained to provide for laboratory pavement design tests subsequently described.

a. Fine and coarse aggregate. Sampling of fine and coarse aggregate will be in accordance with ASTM D 75.

b. Mineral filler. Sampling of mineral filler will be in accordance with ASTM C 183.

c. Asphalt cement, tar cement, and rubberized tar. Sampling of all bituminous materials will be in accordance with ASTM D 140.

A2-3. Testing of pavement materials.

a. Tests on aggregates. Aggregates for use in bituminous pavements should be clean, hard, and durable. Aggregates that are angular in shape generally provide more stable pavements than do rounded ones. In most cases, aggregates will be supplied from established sources where laboratory testing has taken place. Existing laboratory tests should be utilized to the greatest extent possible in providing design data.

(1) Sieve analysis. A sieve analysis of the aggregates considered for use in a paving mix is of value in several respects. An experienced engineer can obtain general information from the grading curve as to the suitability of the aggregate for a paving mix, the quantity of bitumen required, and whether or not mineral filler should be added. Also, a sieve analysis is required if the aggregate is to be used in laboratory tests for paving mix design, as described later. Sieve analyses of fine and coarse aggregates are to be in accordance with ASTM C 136. Figure A-1 is a form suggested for use in recording and calculating data obtained from sieve analysis. Mechanical analysis data for typical coarse aggregate, fine aggregate, sand, and mineral filler used in a paving mixture are shown in figure A-1.

(2) Specific gravity. Specific gravity values for aggregates used in a paving mix are required in the computation of percent voids total mix and percent voids filled with bitumen in the compacted specimens. Criteria have been established to furnish limiting values for these factors. However, specific gravity values must be determined with care and in accordance with specified procedures in order that application of the criteria will be valid. Two different specific gravity determinations are provided, and the selection of the appropriate test procedures depends on the water absorption of each aggregate blend.

(a) ASTM apparent specific gravity. Apparent specific gravity of the fine and coarse aggregate need be used only with aggregate blends showing water absorption of less than 2.5 percent. The apparent specific gravity is to be determined in accordance with ASTM C 127 for coarse aggregate, ASTM C 128 for fine aggregate, and ASTM C 188 or D 854 (whichever is applicable) for mineral filler. Figure A-2 is a form suggested for use in recording data from these tests. Typical data have been supplied in this form as an illustration of its use. Properly weighted values, based on the amount of each type of material in a given blend, should be used in computations subsequently discussed.

(b) Bulk-impregnated specific gravity. For aggregate blends showing water absorption to be 2.5 percent or greater, the bulk-impregnated specific gravity is to be used. This specific gravity will be determined in accordance with the procedure outlined in Method 105, MIL-STD-620.

SIEVE ANALYSIS

JOB NO: | PROJECT: TYPICAL MIX | DATE:

STOCKPILE SAMPLES DRY GRADATION

SAMPLE NO. Crushed Coarse Aggregate

U.S. STAND. SIEVE NO.	WEIGHT RETAINED	% RETAINED	% PASS
3/4			100
1/2	225.9	30.0	70.0
3/8	267.3	35.5	34.5
NO. 4	237.2	31.5	3.0
NO. 8	22.6	3.0	
NO. 16			
NO. 30			
NO. 50			
NO. 100			
NO. 200			
-200			
TOTAL	753.0		

WEIGHT ORIGINAL SAMPLE

SAMPLE NO. Crushed Fine Aggregate

U.S. STAND. SIEVE NO.	WEIGHT RETAINED	% RETAINED	% PASS
3/4			
1/2			100
3/8	1.1	0.2	99.8
NO. 4	53.9	9.8	90.0
NO. 8	104.6	19.0	71.0
NO. 16	104.6	19.0	52.0
NO. 30	96.3	17.5	34.5
NO. 50	82.5	15.0	19.5
NO. 100	60.5	11.0	8.5
NO. 200	30.3	5.5	3.0
-200	16.5	3.0	
TOTAL	550.3		

WEIGHT ORIGINAL SAMPLE

WASHED GRADATION

SAMPLE NO. Natural Sand

U.S. STAND. SIEVE NO.	WEIGHT RETAINED	% RETAINED	% PASS
3/4			
1/2			
3/8			
NO. 4			
NO. 8			
NO. 16			
NO. 30			100
NO. 50	9.4	4.5	95.5
NO. 100	54.6	26.0	69.5
NO. 200	124.9	59.5	10.0
-200 (T)	21.0	10.0	
TOTAL	209.9		

(A) WEIGHT ORIGINAL SAMPLE 209.2 GM
(B) WEIGHT AFTER WASHED 193.7 GM
(C) WASH LOSS (A - B) 15.5 GM
(S) -200 FROM SIEVING 5.5 GM
(T) TOTAL -200 C + S 21.0 GM
USE "T" TO CALCULATE PERCENTAGES

SAMPLE NO. Limestone Filler

U.S. STAND. SIEVE NO.	WEIGHT RETAINED	% RETAINED	% PASS
3/4			
1/2			
3/8			
NO. 4			
NO. 8			
NO. 16			
NO. 30			
NO. 50			100
NO. 100	2.3	2.0	98.0
NO. 200	9.4	8.0	90.0
-200 (T)	105.3	90.0	
TOTAL	117.0		

(A) WEIGHT ORIGINAL SAMPLE 117.4 GM
(B) WEIGHT AFTER WASHED 18.9 GM
(C) WASH LOSS (A - B) 98.5 GM
(S) -200 FROM SIEVING 6.8 GM
(T) TOTAL -2000 C + S 105.3 GM
USE "T" TO CALCULATE PERCENTAGES

TESTED BY: | COMPUTED BY: | CHECKED BY:

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FIGURE A-1. SIEVE ANALYSIS

SPECIFIC GRAVITY OF BITUMINOUS MIX COMPONENTS					DATE
PROJECT	JOB TYPICAL MIX				
COARSE AGGREGATE					
MATERIAL PASSING 3/4" SIEVE AND RETAINED ON 3/8" SIEVE	UNITS				
SAMPLE NUMBER Coarse aggregate					
1. WEIGHT OF OVEN - DRY AGGREGATE	GM.	378.3			
2. WEIGHT OF SATURATED AGGREGATE IN WATER	GM.	241.0			
3. DIFFERENCE (1.-2.)	GM.	137.3			
APPARENT SPECIFIC GRAVITY, $G = \frac{(1.)}{(3.)}$	2.755				
FINE AGGREGATE					
MATERIAL PASSING NUMBER 3/8" SIEVE	UNITS				
SAMPLE NUMBER Natural sand					
4. WEIGHT OF OVEN - DRY MATERIAL	GM.	478.8			
5. WEIGHT OF FLASK FILLED WITH WATER AT 20°C	GM.	678.6			
6. SUM (4.+5.)	GM.	1157.4			
7. WEIGHT OF FLASK + AGGREGATE + WATER AT 20°C,	GM.	977.4			
8. DIFFERENCE (6.-7.)	GM.	180.0			
APPARENT SPECIFIC GRAVITY, $G = \left(\frac{4.}{8.}\right)$	2.660				
FILLER	UNITS				
SAMPLE NUMBER Limestone Filler					
9. WEIGHT OF OVEN - DRY MATERIAL	GM.	466.5			
10. WEIGHT OF FLASK FILLED WITH WATER AT 20°C,	GM.	676.1			
11. SUM (9.+10.)	GM.	1142.6			
12. WEIGHT OF FLASK + AGGREGATE + WATER AT 20°C,	GM.	973.8			
13. DIFFERENCE (11.-12.)	GM.	168.8			
APPARENT SPECIFIC GRAVITY, $G = \left(\frac{9.}{13.}\right)$	2.764				
BINDER	UNITS				
SAMPLE NUMBER 6873					
14. WEIGHT OF PYCNOMETER FILLED WITH WATER	GM.	61.9595			
15. WEIGHT OF EMPTY PYCNOMETER	GM.	37.9215			
16. WEIGHT OF WATER (14.-15.)	GM.	24.0380			
17. WEIGHT OF PYCNOMETER + BINDER	GM.	47.8617			
18. WEIGHT OF BINDER (17.-15.)	GM.	9.9402			
19. WEIGHT OF PYCNOMETER + BINDER + WATER TO FILL PYCNOMETER	GM.	62.1568			
20. WEIGHT OF WATER TO FILL PYCNOMETER (19.-17.)	GM.	47.8617			
21. WEIGHT OF WATER DISPLACED BY BINDER	GM.	9.7429			
APPARENT SPECIFIC GRAVITY, $G = \left(\frac{18.}{20.}\right)$	1.020				
REMARKS					
TECHNICIAN (Signature)	COMPUTED BY (Signature)	CHECKED BY (Signature)			

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FIGURE A-2. SPECIFIC GRAVITY OF BITUMINOUS MIX COMPONENTS

(3) Wear requirements for coarse aggregate. The determination of percentage of wear for coarse aggregates may not be necessary if the aggregate has been found satisfactory by previous tests. However, coarse aggregates obtained from new or doubtful deposits must be tested for conformance to specification requirements using ASTM C 131.

(4) Soundness test. The soundness test is used where damage from freezing is expected to be a problem. It is not necessary to conduct the soundness test on aggregate that has been found satisfactory by previous tests. However, aggregate obtained from new or doubtful deposits will be tested for conformance to specification requirements using ASTM C 88.

(5) Swell test. Experience has indicated that bituminous pavements produced from clean, sound stone, slag, or gravel aggregates and from mineral filler produced from limestone will show values in the swell test of less than 1.5 percent. However, aggregates considered to be of doubtful character will be tested for conformance to specification requirements for percentage of swell in accordance with AASHTO T 101.

(6) Immersion-compression test. This test should be conducted on all paving mixes considered for construction of pavements. (See Method 104, MIL-STD-620).

b. Tests on mineral filler. Some mineral fillers have been found to be more satisfactory in asphalt paving mixtures than others. For example, fine sands and clays are normally less suitable fillers than limestone filler or portland cement. Well-graded materials are more suitable than poorly graded materials. A limited amount of laboratory work has indicated that mineral fillers of reasonably uniform gradation and falling within the limits set forth in paragraph A2-3.f. hereinafter, are generally satisfactory. Satisfactory pavements may be designed using commercial fillers that conform to ASTM Standards. The specific gravity of the mineral filler is required in void computation. It will be determined in accordance with ASTM D 854, or alternatively, ASTM C 188, except that when the bulk-impregnated specific gravity is used, the mineral filler is to be included in the blended aggregate. (See Method 103, MIL-STD-620). Figure A-2 is a form suggested for tabulation and computation of these data; typical data have been entered in this form to illustrate its use.

c. Tests on bitumen. Test requirements for asphalt cement, tar for rubberized-tar blends, rubberized-tar blends, and tar are outlined in the mobilization specifications. Figure A-2 is a form suggested for use in determining specific gravity of bitumen; typical data are included in this form.

d. Selection of materials for mix design. The first step in the design of a paving mix is the tentative selection of materials. The bitumen used in the laboratory tests must be the same as that which will be used in field construction. The selection of aggregates and mineral filler for the paving mix is more involved than the selection of the bitumen. Aggregates and mineral fillers that do not meet the requirements of the specifications previously discussed should be eliminated from further consideration. The remaining aggregates and filler must then be examined from both technical and economical viewpoints. The final objective is to determine the most economical blend of aggregates and mineral filler that will produce a pavement meeting the engineering requirements set forth in this manual. In general, several blends should be selected for laboratory mix-design tests. The mix-design gradation (i.e., job-mix formula) plus or minus job-mix tolerances must fall within the gradation tolerances specified in the appropriate guide specification.

e. Combining aggregates. In the production of paving mixes, it is generally necessary to combine aggregates from two or more sources. Mathematical equations are available for making such combinations, but they are not presented herein because they are lengthy and normally it is easier to use trial-and-error procedures. Methods and procedures described herein will permit determination of the most suitable aggregate or blend available, and will prescribe the proper bitumen content for the particular aggregate blend determined to be the most suitable. Whenever a paving mix will not meet established criteria, as subsequently outlined, it is necessary either to improve the gradation of the aggregate being used or to use another aggregate. The choice as to improvement of gradation or the use of another aggregate is a matter of engineering judgment involving an analysis of the available aggregate supplies and various economic considerations.

f. Addition of mineral filler. The filler requirements of each aggregate blend must be estimated after the blends to be tested in the laboratory have been selected. Considerations should be given to the items discussed in paragraph A2-3.b. in selecting the mineral filler to be used. The quantity of mineral filler to be added depends on several factors, among which are the amount of filler naturally present in the aggregate, desired reduction in voids, the extent to which additional increments of filler will decrease the optimum bitumen content of the mixture, the extent to which it may be necessary to improve the stability of the mixture, and the cost of the filler. The addition of mineral filler reduces the quantity of bitumen required for the paving mixture. The addition of excessive amounts of filler is not economical, as a limit is reached at which no further reduction in optimum bitumen content occurs with an increase in filler. It also has been indicated that the addition of a satisfactory mineral filler within practical limits increases the stability of a paving mixture. Excessive amount of filler, however, may decrease the durability of the paving mixture. Therefore, while the addition of some mineral filler is normally beneficial to the paving mixture, the addition of large quantities of filler not only is uneconomical, but may also be detrimental to the paving mixture. Experience has indicated that filler contents should not exceed about 10 percent for bituminous concretes and about 20 percent for sand asphalts. Practical considerations usually will dictate quantities of about 5 percent filler for bituminous concrete and 10 percent for sand asphalts. When there has been no previous experience with a particular aggregate, it may be desirable to conduct laboratory tests at more than one filler content in order that the best mixture can be selected.

A2-4. Laboratory testing for mix design.

a. General procedure. Laboratory testing will indicate the properties that each blend selected would have after being subjected to appreciable traffic. A final selection of aggregate blend and filler will be based on these data with due consideration to relative costs of the various mixes. The procedures set forth in the following paragraphs are directly applicable to all mixes containing not more than 10 percent of aggregate retained on the 1-inch sieve. The procedure to follow when a mix contains more than 10 percent aggregate exceeding the 1-inch-maximum size is outlined in Method 103, MIL-STD-620.

b. Preparation of test specimens. The selection of materials for use in designing the paving mix was discussed in paragraph 6-2. For purposes of illustration, suppose that it has been determined that an aggregate gradation for a hot-mix design should be the median of the limiting gradation curves in figure A-3. This is the blend on which design data are required. The initial pavement mix design tests will usually be made in a central testing laboratory. The initial tests will be conducted on samples of stockpile materials submitted by the Contractor. Paragraph (1) below outlines the procedure for proportioning stockpile samples to produce a blend of materials to meet a specified gradation. The final mix will be based on bin samples taken from the bituminous plant; in this step, it will again be necessary to determine what proportions of the bin materials will be required to meet a specified gradation. The final mix design will usually be made in a field laboratory near the plant, or the bin samples may be sent to the central laboratory that conducted the initial design tests on the stockpile samples. Paragraph (2) below outlines the procedure for combining processed bin samples to meet a specified gradation.

(1) Proportioning of stockpile samples. As a preliminary step in mixture design and manufacture, it is necessary to determine the approximate proportions of the different available stockpiled materials required to produce the desired gradation of aggregate. This is necessary in order to determine whether a suitable blend can be produced and, if so, the approximate proportion of aggregates to be fed from the cold feed into the dryer. Sieve analyses are run on material from each of the stockpiles and these data entered in a form as

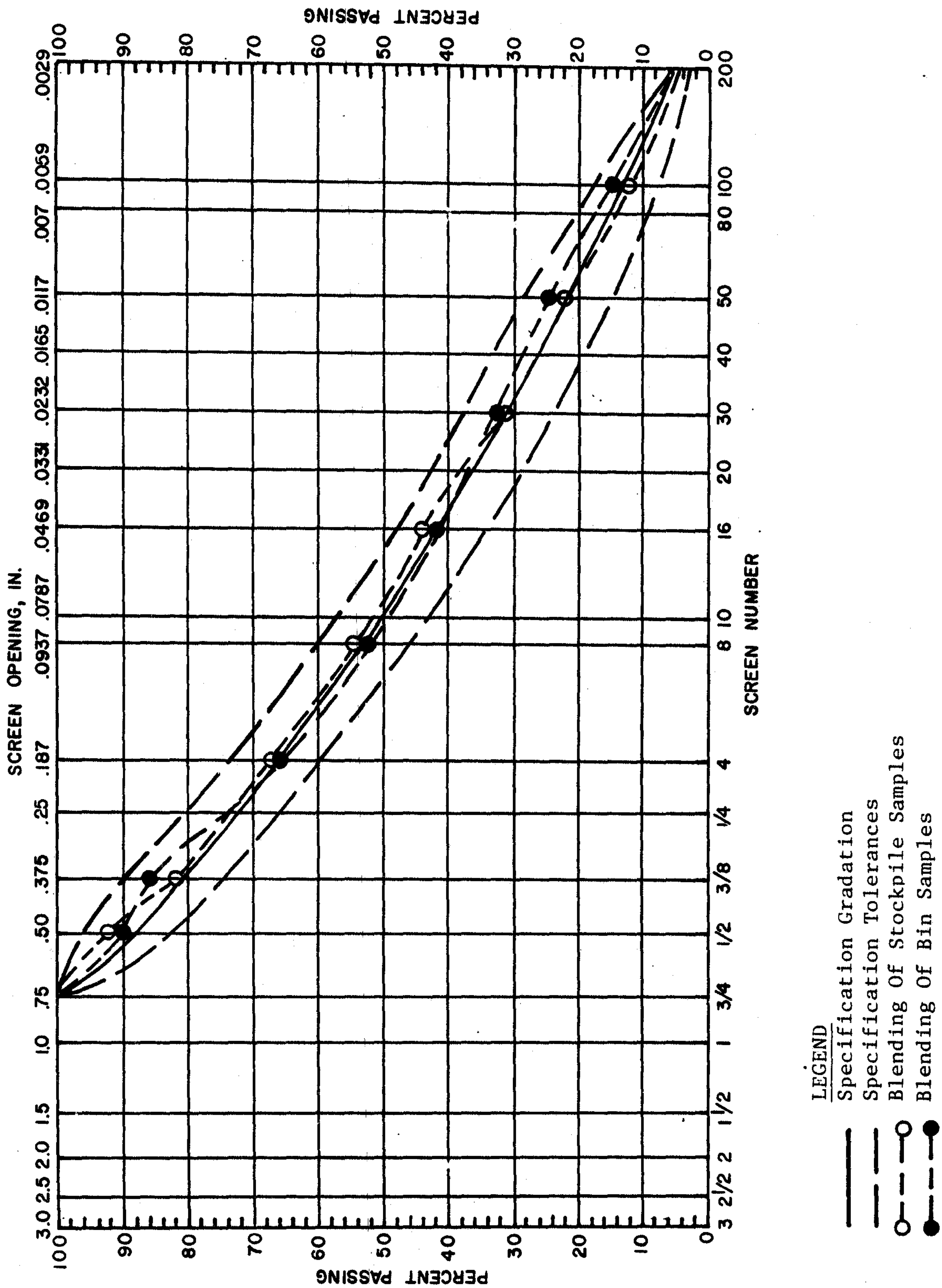

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FIGURE A-3. GRADATION DATA FOR HOT MIX DESIGN illustrated at the top of figure A-4. The data are shown graphically in figure A-5. These fractions must be combined to produce the desired blend. The percentage of each fraction required to produce this blend is entered in the form at the middle of figure A-4; these percentages are most easily determined by trial-and-error calculations.

(2) Proportioning of bin samples. Once it is demonstrated that a suitable blend can be prepared from the available materials, then samples of these materials can be processed for use in the laboratory design tests. Sieve analyses must be conducted for each batch of processed aggregate. The processed aggregates are comparable to those obtained in the hot bins of an asphalt plant. Results from these sieve analyses should be entered in a form as illustrated at the top of figure A-6. The data are shown graphically in figure A-7. A study of the data from the sieve analysis of the processed samples indicates that, of the material processed to pass the 3/4-inch sieve and be retained on 3/8-inch sieve, 76 percent was retained on the 3/8-inch sieve. The desired blend requires 18 percent to be retained on the 3/8-inch sieve; and since all of the 3/4- to 3/8-inch fraction in the desired blend will come from this 3/4- to 3/8-inch fraction, in the first trial, 18 percent of the 3/4- to 3/8-inch was used. The percentage data are entered in the second column (percent used) of the center portion (trial No. 1) of figure A-6 as illustrated. These percentage figures are then used to determine the proportional part of each aggregate size in each of the separated fractions. If the combined blends contained 18 percent of the 3/4- to 3/8-inch fraction, then 18.0, 9.0, 4.3, 1.3, and 0.2 percent of the total blend would pass the 3/4-, 1/2-, 3/8-inch, No. 4 sieves, respectively. The same reasoning is used for the 3/8-inch to No. 8 fraction. The data indicate 90 percent retained on the No. 8 sieve, and the desired blend calls for 29 percent of the 3/8-inch to No. 8 fraction to be retained on the No. 8. Nearly all of this fraction will come from the 3/8-inch to No. 8 fraction bin; therefore, 34 percent has been used as a trial. This procedure is then followed for the other fractions, the data being entered in figure A-6 as indicated, and the grading of the combined blend is determined by the addition of all percentages under each screen-size heading. The grading of this recombined blend is then checked against the desired grading (fig A-6). One or two trials are usually sufficient to produce a combination of the desired grading within the allowable tolerances.

c. Bitumen contents for specimens. The quantity of bitumen required for a particular aggregate is one of the most important factors in the design of a paving mixture; it can be determined by procedures described in the following paragraph. However, an estimate for the optimum amount of bitumen based on total weight of mix must be made in order to start the laboratory tests. Laboratory tests normally are conducted for a minimum of five bitumen contents: two above, two below, and one at the estimated optimum content. One percent incremental changes of bitumen may be used for preliminary work;

BITUMINOUS MIX DESIGN
(TRIAL METHOD)

JOB NO.:	PROJECT TYPICAL MIX	DATE:

GRADATION OF MATERIAL

SIEVE SIZE	PERCENT USED	SIEVE SIZE - PERCENT PASSING										
		1	3/4	1/2	3/8	4	8	16	30	50	100	200
Cr C A	100		100	70.0	34.5	3.0						
Cr F A	100		100	100	99.8	90.0	71.0	52.0	34.5	19.5	8.5	3.0
Sand	100		100	100	100	100	100	100	100	95.5	69.5	10.0
LSF	100		100	100	100	100	100	100	100	100	98.0	90.0

COMBINED GRADATION FOR BLEND - TRAIL NO. 1

SIEVE SIZE	PERCENT USED	SIEVE SIZE - PERCENT PASSING										
		1	3/4	1/2	3/8	4	8	16	30	50	100	200
Cr C A	27.0		27.0	18.9	9.3	0.8						
Cr F A	63.0		63.0	63.0	62.9	56.7	44.7	32.8	21.7	12.3	5.4	1.9
Sand	8.0		8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.7	5.6	0.8
LSF	2.0		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.8
BLEND			100	91.9	82.2	67.5		42.8	31.7	22.0	12.0	4.5
DESIRED			100	89.0	82.0	67.0		41.0	31.0	22.0	13.0	4.5

COMBINED GRADATION FOR BLEND - TRAIL NO. ____

SIEVE SIZE	PERCENT USED	SIEVE SIZE - PERCENT PASSING										
		1	3/4	1/2	3/8	4	8	16	30	50	100	200
BLEND												
DESIRED												

COMPUTED BY:	CHECKED BY:

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FIGURE A-4. BLENDING OF STOCKPILE SAMPLES

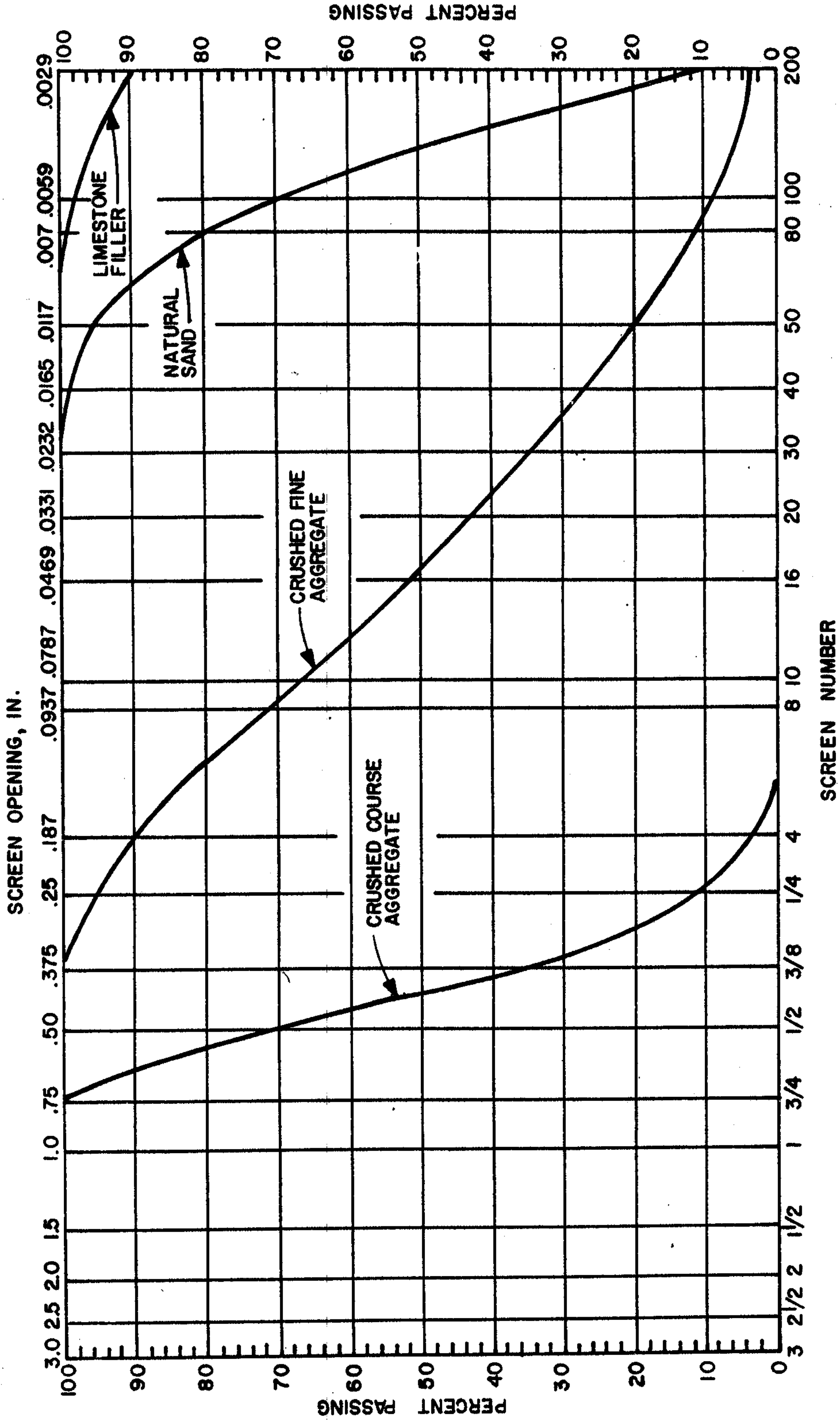

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FIGURE A-5. GRADATION DATA FOR STOCKPILE AGGREGATES

BITUMINOUS MIX DESIGN
(TRIAL METHOD)

JOB NO.:	PROJECT TYPICAL MIX	DATE:

GRADATION OF MATERIAL

SIEVE SIZE	PERCENT USED	SIEVE SIZE - PERCENT PASSING										
		1	3/4	1/2	3/8	4	8	16	30	50	100	200
3/4-3/8	100		100	50.0	24.0	7.0	1.0					
3/8-8	100		100	100	100	49.0	10.0	1.0				
-No. 8	100		100	100	100	100	100	84.0	65.0	46.5	26.5	5.0
LSF	100		100	100	100	100	100	100	100	100	98.0	90.0

COMBINED GRADATION FOR BLEND - TRAIL NO. 1

SIEVE SIZE	PERCENT USED	SIEVE SIZE - PERCENT PASSING										
		1	3/4	1/2	3/8	4	8	16	30	50	100	200
3/4-3/8	18.0		18.0	9.0	4.3	1.3	0.2					
3/8-8	34.0		34.0	34.0	34.0	16.6	3.4	0.3				
-No. 8	45.0		45.0	45.0	45.0	45.0	45.0	37.8	29.3	20.9	11.9	2.2
LSF	3.0		3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.9	2.7
BLEND			100	91.0	86.3	65.9	51.6	41.1	32.3	23.9	14.8	4.9
DESIRED			100	89.0	82.0	67.0	53.0	41.0	31.0	22.0	13.0	4.5

COMBINED GRADATION FOR BLEND - TRAIL NO. ______

SIEVE SIZE	PERCENT USED	SIEVE SIZE - PERCENT PASSING										
		1	3/4	1/2	3/8	4	8	16	30	50	100	200
BLEND												
DESIRED												

COMPUTED BY:	CHECKED BY:

U. S. Army Corps of Engineers

FIGURE A-6. BLENDING OF STOCKPILE SAMPLES

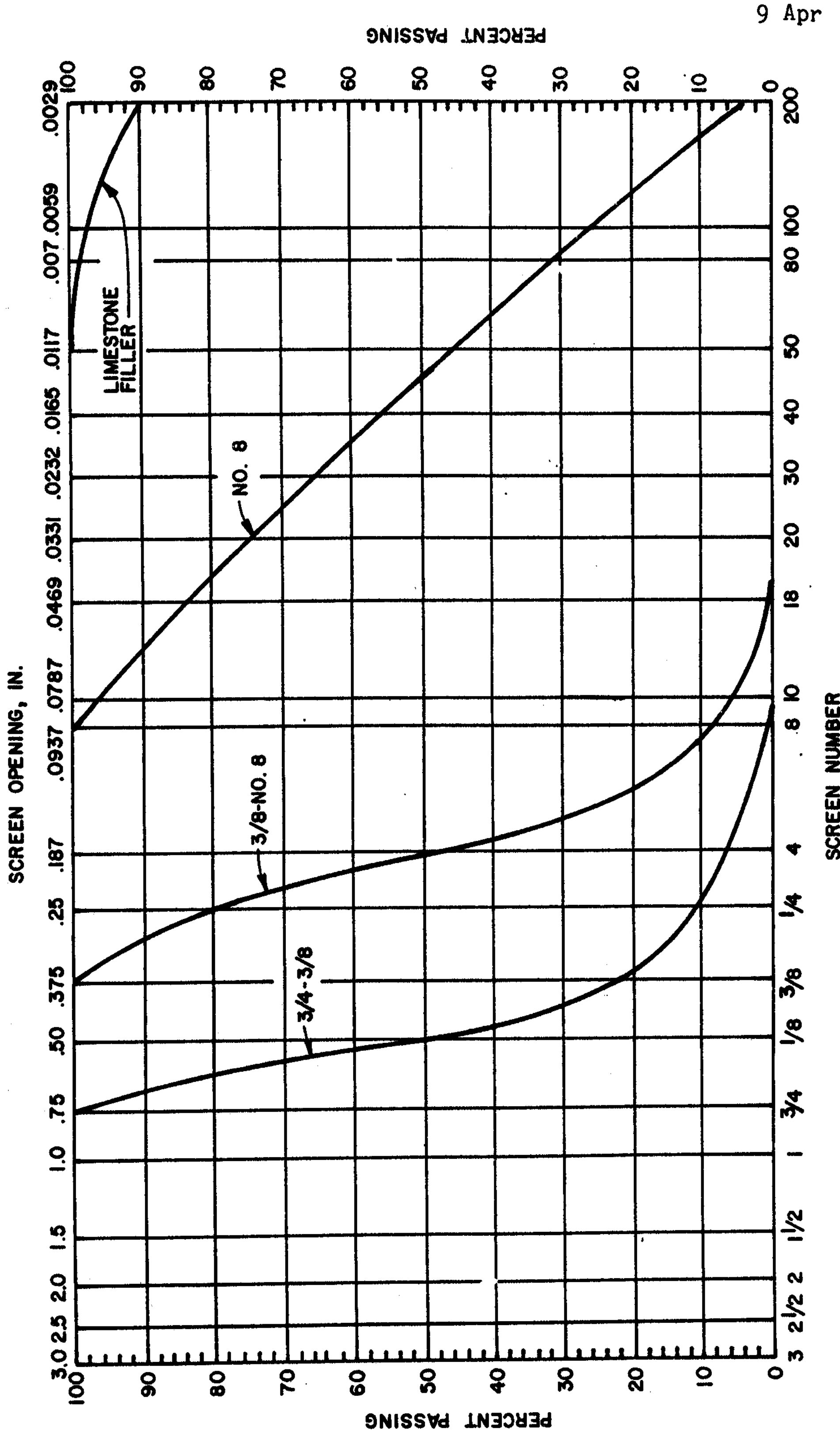

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FIGURE A-7. GRADATION DATA FOR BIN SAMPLES however, increments of 1/2 percent generally are used when the approximate optimum bitumen content is known, and for final design. Tar and rubberized tar generally require about the same volume of bitumen, but since tar is heavier than asphalt, the percentage by weight will be somewhat higher.

d. Selection of design method. The Corps of Engineers authorize two methods of design of bituminous paving mixtures in the laboratory, namely the Marshall procedure and the gyratory method. The procedures for conducting these mix-design tests are described in Methods 100 and 102, MIL-STD-620, respectively. Method 101 is complementary to both Methods 100 and 102. Laboratory design compaction requirements are summarized as follows:

Type of Traffic	Design Compaction Requirements
Tire pressures less than 100 psi	50 blows or equivalent gyratory compaction
Tire pressures 100-250 in non-channelized traffic area, solid tires and tracked vehicles	75 blows or equivalent gyratory compaction
Tire pressures 250 psi and above plus any channelized traffic area	Gyratory compaction mandatory

e. Tabulation of data. After the laboratory design method has been selected and test specimens prepared, data should be tabulated on forms similar to those shown in Methods 100 and 101 if the Marshall procedure is used. These forms would also be used if the gyratory procedure is used, as well as the forms shown in Method 102 normally used for the gyratory procedure. A form similar to that shown in figure A-8 will facilitate tabulation of specimen test propery data and is preferable to similar but less complete forms used in Methods 100 and 101 of MIL-STD-620. Plots of data from figure A-8 for stability, flow, unit weight, percent voids total mix, and percent voids filled with bitumen should be made, using a form similar to that shown in figure A-9. The average actual specific gravity is obtained for each set of test specimens, as shown in column G of figure A-8. Each average value is multiplied by 62.4 to obtain density in pounds per cubic foot, and these data are entered in column L. The density values thus obtained are plotted as shown on figure A-9, and the best smooth curve is then drawn. New density values are read from the curve for points that may be off the curve, as is the case for density at 4.0 percent bitumen. The new density for 4.0 percent bitumen content is entered in column L beneath the original figure. The new density is divided by 62.4 and

COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

Job No.: | Project: Typical Mix | Description of Blend: | Date:

Specimen No.	Asphalt Cement - %	Thickness In.	Weight-Grams In Air	Weight-Grams In Water	Volume cc	Specific Gravity Actual	Specific Gravity Theor.	AC by Volume - %	Voids - Percent Total Mix	Voids - Percent Filled	Unit Weight Total Mix lb/Cu Ft	Stability - Lb Measured	Stability - Lb Converted	Flow Units of 1/100 In.
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
					(D-E)	(D)/(F)		BxG/(Sp. Gr. of AC)	G/(100-100H)	I/(I+J)	(Gx62.4)		*	
A-3.5 1	3.5		1228.3	716.3	512.0	2.399						2020	2020	11
2			1219.5	712.2	507.3	2.404						1862	1936	10
3			1205.5	705.3	500.2	2.410						1821	1894	8
4			1206.2	708.4	497.8	2.423						1892	1968	8
Avg						2.409					150.3		1955	9
Curve						2.409	2.579	8.3	6.6	55.7	150.3			
A-4.0 1	4.0		1276.9	747.3	529.6	2.411						2110	2026	10
2			1252.6	733.3	519.3	2.412						2025	2025	9
3			1243.5	730.7	512.8	2.425						1995	1995	9
4			1230.4	722.8	507.6	2.424						2020	2101	9
Avg						2.418					150.9		2037	9
Curve						2.421	2.559	9.5	5.4	63.8	151.1			
A-4.5 1	4.5		1254.4	738.2	516.2	2.430						2050	2050	12
2			1238.3	726.8	511.5	2.421						2095	2095	9
3			1239.0	724.9	514.1	2.410						2110	2110	10
4			1273.5	752.0	521.5	2.442						2045	2045	10
Avg						2.426					151.4		2075	10
Curve						2.426	2.539	10.7	4.5	70.4	151.4			
A-5.0 1	5.0		1237.9	727.0	510.9	2.423						1875	1875	14
2			1300.0	763.7	536.3	2.424						2130	1981	10
3			1273.6	746.9	526.7	2.418						1900	1824	12
4			1247.9	731.8	516.1	2.418						1855	1855	12
Avg						2.421					151.1		1884	12
Curve						2.421	2.519	11.9	3.9	75.3	151.1			
A-5.5 1	5.5		1237.3	724.1	513.2	2.411						1450	1450	12
2			1264.0	740.6	523.4	2.415						1530	1469	14
3			1286.4	752.4	534.0	2.409						1615	1550	13
4			1253.5	733.8	519.7	2.412						1505	1505	16
Avg						2.412					150.5		1494	14
Curve						2.409	2.500	13.0	3.6	78.3	150.3			

*From conversion table | Computed by: | Checked by:

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FIGURE A-8. COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

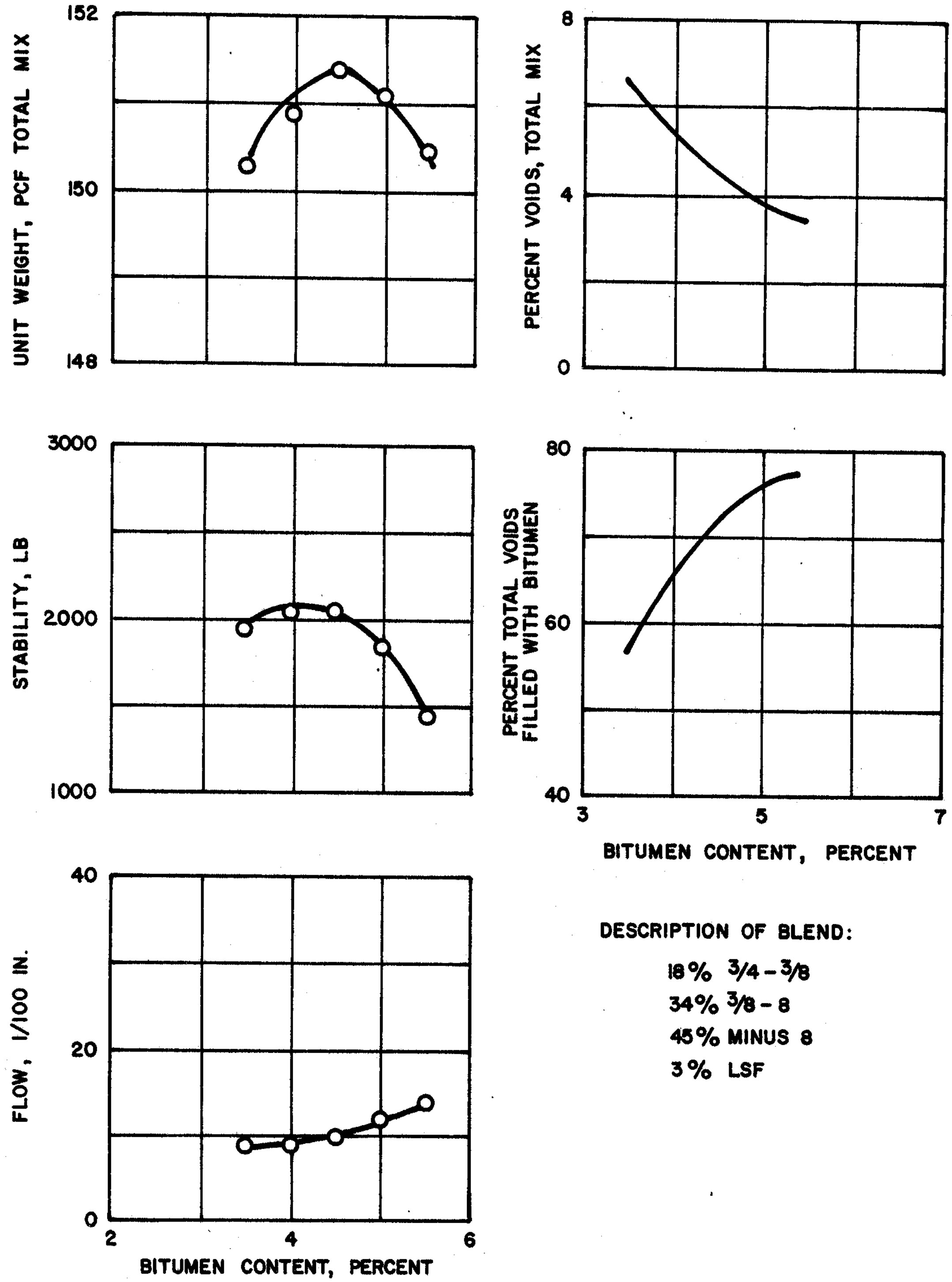

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FIGURE A-9. ASPHALT PAVING MIX DESIGN (TYPICAL MIX) the corrected specific gravity thus obtained is entered in column G; it is called the "curve" specific gravity in figure A-8. The curve specific gravity values for each bitumen content, whether they are corrected or original values, are used to compute the voids data shown in columns I, J, and K. The data from columns J and K are used to plot curves for percent voids total mix and voids filled with bitumen, respectively on figure A-9.

f. Relationship of test properties to bitumen content. Test property curves, plotted as described above, have been found to follow a reasonably consistent pattern for mixes made with penetration grades of asphalt cement, tar cement, and rubberized tar. Trends generally noted are outlined as follows.

(1) Flow. The flow value increases with increasing bitumen content at a progressive rate except at very low bitumen contents.

(2) Stability. The Marshall stability increases with increasing bitumen content up to a certain point, after which it decreases.

(3) Unit weight. The curve for unit weight of total mix is similar to the curve for stability, except that the peak of the unit-weight curve is normally at a slightly higher bitumen content than the peak of the stability curve.

(4) Voids total mix. Voids total mix decreased with increasing bitumen content in the lower range of bitumen contents. There is a minimum void content for each aggregate blend and compaction effort used herein, and the voids cannot be decreased below this minimum without increasing or otherwise changing the compaction effort. The void content of the compacted mix approaches this minimum void content as the bitumen content of the mix is increased.

(5) Voids filled with bitumen. Percent voids filled with bitumen increases with increasing bitumen content and approaches a maximum value in much the same manner as the voids total mix discussed above approaches a minimum value.

g. Requirement for additional test specimens. Curves illustrated in figure A-9 are typical of those normally obtained when penetration grades of asphalt cement, tar cement, or rubberized tar are used with aggregate mixes. Aggregate blends may be encountered that will furnish erratic data such that plotting of the typical curves is difficult. In a majority of these cases, an increase in the number of specimens tested at each bitumen content will normally result in data that will plot as typical curves.

A2-5. Optimum bitumen and design test properties.

a. Selection of bitumen content. Investigational work has indicated that the optimum bitumen content is one of the most important factors in the proper design of a bituminous paving mixture. Extensive research and pavement behavior studies have resulted in establishment of certain criteria for determining the proper or optimum bitumen content for a given blend of aggregates. Criteria have also been established to determine whether the aggregate will furnish a satisfactory paving mix at the selected optimum bitumen content.

b. Determination of optimum bitumen content and satisfactoriness of mix.

(1) Marshall method. Data plotted in graphical form in figure A-9 are used to determine optimum bitumen content. In addition, optimum bitumen content and satisfactoriness of the mix are determined on table A-1 if the water absorption of the aggregate blend is not more than 2.5 percent. If the water absorption is greater than 2.5 percent and the bulk impregnated procedure is used in the mix design tests, table A-2 is used to determine the optimum bitumen content and satisfactoriness of the mix. Separate criteria are shown for use where specimens were prepared with 50- and 75-blow compaction efforts.

(a) Typical example. The application of the above criteria for determinations of optimum bitumen content and probable satisfactoriness of the paving mix, and using the curves in figure A-9, is illustrated below. The illustration is for a mix compacted with 75-blow effort.

Determination of Optimum Bitumen Content

Peak of stability curve	4.3 percent
Peak of unit-weight curve	4.5 percent
Four percent voids in total mix (bituminous concrete)	4.8 percent
Seventy-five percent total voids filled with asphalt (bituminous concrete)	4.9 percent
Average	4.6 percent

The optimum bitumen content of the mix being used as an example is considered to be 4.6 percent based on the weight of the total mix.

(b) Determination of the probable satisfactoriness of the paving mixture.

Table A-1. Design Criteria For Use With ASTM Apparent Specific Gravity

This table is for use with aggregate blends showing water absorption up to 2.5 percent

Test Property	Type of Mix	Optimum Bitumen Content 50 Blows	Optimum Bitumen Content 75 Blows	Satisfactoriness of Mix 50 Blows	Satisfactoriness of Mix 75 Blows
Marshall stability	Bituminous-concrete surface course	Peak of curve	Peak of curve	500 lb. or higher	1,800 lb. or higher
	Bituminous-concrete intermediate course	Peak of curve (a)	Peak of curve (a)	500 lb. or higher	1,800 lb. or higher
	Sand asphalt	Peak of curve	(b)	500 lb. or higher	(b)
Unit weight	Bituminous-concrete surface course	Peak of curve	Peak of curve	Not used	Not used
	Bituminous-concrete intermediate course	Not used	Not used	Not used	Not used
	Sand asphalt	Peak of curve	(b)	Not used	Not used
Flow	Bituminous-concrete surface course	Not used	Not used	20 or less	16 or less
	Bituminous-concrete intermediate course	Not used	Not used	20 or less	16 or less
	Sand asphalt	Not used	Not used	20 or less	(b)
Percent voids total mix	Bituminous-concrete surface course	4	4	3-5	3-5
	Bituminous-concrete intermediate course	5	5	4-6	5-7
	Sand asphalt	6	(b)	5-7	(b)
Percent filled with bitumen	Bituminous-concrete surface course	80	75	75-85	70-80
	Bituminous-concrete intermediate course	70 (a)	60 (a)	65-75	50-70
	Sand asphalt	70	(b)	65-75	(b)

Notes:

(a) If the inclusion of bitumen contents at these points in the average causes the voids total mix to fall outside the limits, then the optimum bitumen content should be adjusted so that the voids total mix are within the limits.

(b) Sand asphalt will not be used in designing pavements for traffic with tire pressures in excess of 100 psi.

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Table A-2. Design Criteria For Use With Bulk Impregnated Specific Gravity

This table is for use with aggregate blends showing water absorption greater than 2.5 percent

Test Property	Type of Mix	Optimum Bitumen Content		Satisfactoriness of Mix	
		50 Blows	75 Blows	50 Blows	75 Blows
Marshall stability	Bituminous-concrete surface course	Peak of curve	Peak of curve	500 lb. or higher	1,800 lb. or higher
	Bituminous-concrete intermediate course	Peak of curve (a)	Peak of curve (a)	500 lb. or higher	1,800 lb. or higher
	Sand asphalt	Peak of curve	(b)	500 lb. or higher	(b)
Unit weight	Bituminous-concrete surface course	Peak of curve	Peak of curve	Not used	Not used
	Bituminous-concrete intermediate course	Not used	Not used	Not used	Not used
	Sand asphalt	Peak of curve	(b)	Not used	Not used
Flow	Bituminous-concrete surface course	Not used	Not used	20 or less	16 or less
	Bituminous-concrete intermediate course	Not used	Not used	20 or less	16 or less
	Sand asphalt	Not used	Not used	20 or less	(b)
Percent voids total mix	Bituminous-concrete surface course	3	3	2-4	2-4
	Bituminous-concrete intermediate course	4	5	3-5	3-5
	Sand asphalt	5	(b)	4-6	(b)
Percent filled with bitumen	Bituminous-concrete surface course	85	80	80-90	75-85
	Bituminous-concrete intermediate course	75 (a)	65 (a)	70-80	55-75
	Sand asphalt	75	(b)	70-80	(b)

Notes:

(a) If the inclusion of bitumen contents at these points in the average causes the voids total mix to fall outside the limits, then the optimum bitumen content should be adjusted so that the voids total mix are within the limits.

(b) Sand asphalt will not be used in designing pavements for traffic with tire pressures in excess of 100 psi.

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Test Property	At Optimum or 4.6 percent Bitumen	Criteria for Satisfactoriness
Flow	11	Less than 16
Stability	2,050	More than 1,800
Percent voids in total mix	4.3	3-5 percent (bituminous concrete)
Percent total voids filled with bitumen	72	70-80 percent (bituminous concrete)

The paving mix under discussion would be considered satisfactory for normal airfield traffic, since it meets the criteria for satisfactoriness at the bitumen content determined to be optimum.

(2) Gyratory method. Paragraph 4.4 of Method 102, MIL-STD-620 describes the procedure for selecting optimum bitumen content using the gyratory method of design. The principal criteria are the peak of the unit weight aggregate only curve and the gyrograph recordings. Generally, optimum bitumen content occurs at the peak of the unit weight aggregate only curve and at the highest bitumen content at which little or no spreading of the gyrograph trace occurs. The bitumen content determined by these two criteria will usually be nearly identical; if there is a difference, an average figure can be used. In no case, however, should a bitumen content be selected that would be high enough to cause more than faint spreading of the gyrograph trace.

(a) The optimum binder content in most cases will produce a bituminous mixture that will have satisfactory characteristics without resorting to further test procedures. However, it is recommended that the mix be tested for stability and flow; density and voids data should also be obtained. Stability and flow criteria shown in paragraph 2-5.b.(1) for the Marshall procedures should be applied to paving mixtures designed by the gyratory method. It is necessary to determine density at optimum bitumen content to establish field rolling requirements. If the 240 psi, 1-degree, 60 revolutions compaction effort described in paragraph 3.1.1 of Method 102, MIL-STD-620 is used in design of a paving mixture, density values will result that require greater rolling effort in the field to obtain 98 percent of laboratory density than by the Marshall design method.

(b) Selection of optimum bitumen content by the gyratory method may result in the paving mixture having lower percent voids total mix than would be permissible with the Marshall procedure. For example, the voids total mix of a paving mixture designed for traffic by aircraft with tire pressures of 200 psi or higher might be only 2.5

percent, as compared to a specified range of 3 to 5 percent in the Marshall criteria. The lower percent voids total mix is acceptable when using the gyratory procedure. This is because the compaction effort used the laboratory design results in densities in the mix sufficiently high that further densification under traffic is minimized, as compared to lower densities obtained by the Marshall procedure.

c. Selection of paving mix. When two or more paving mixes have been investigated, the one used for field construction should be the most economical mix that satisfies all of the established criteria. The mix showing the highest stability should be selected, if economic considerations are equal.

d. Tolerances for pavement properties. Occassionally it may not be possible, for economic or other reasons, to develop a mix that will meet all of the criteria set forth above. A tolerance of 1 percent of voids in the total mix and 5 percent of total voids filled with bitumen may be allowed in some circumstances, but under no circumstances will the mix be considered satisfactory if the flow value is in excess of 20 or the stability value is less than 500 pounds for mixes compacted with the 50-blow effort, or if the flow is in excess of 16 or the stability less than 1,800 pounds for mixes compacted with the 75-blow effort.

A3. Plant control.

A3-1. Plant operation.

a. Types of plants. Figures A-10, A-11, and A-12 show a typical batch plant, a typical continuous-mix plant, and a dryer drum mixing plant, respectively. It is generally necessary, in the operation of a bituminous paving plant, to combine aggregates from two or more sources to produce an aggregate mixture having the desired gradation. Aggregates from the different sources are fed into the aggregate dryer in the approximate proportions required to produce the desired gradation. This initial proportioning generally is accomplished by means of a hopper-type mechanical feeder on one or more bins that feeds the aggregates into a cold elevator, which, in turn, delivers them to the dryer. The mechanical feeder generally is loaded by a clam shell or other suitable means in the approximate proportions of aggregates desired. The aggregates pass through the dryer where the moisture is driven off and the aggregates are heated to the desired temperature. In the dryer drum mix plant, the binder is added to the aggregate during drying and leaves the dryer as mixed pavement material ready for truck loading. Upon leaving the dryer of batch and continuous-mix plants, the aggregates pass over vibrating screens where they are separated according to size. When using emulsified asphalt as the binder, the dryer operation is omitted. The usual screening equipment for a three-bin plant consists of a rejection screen for eliminating oversize material and screens for dividing the coarse aggregate into

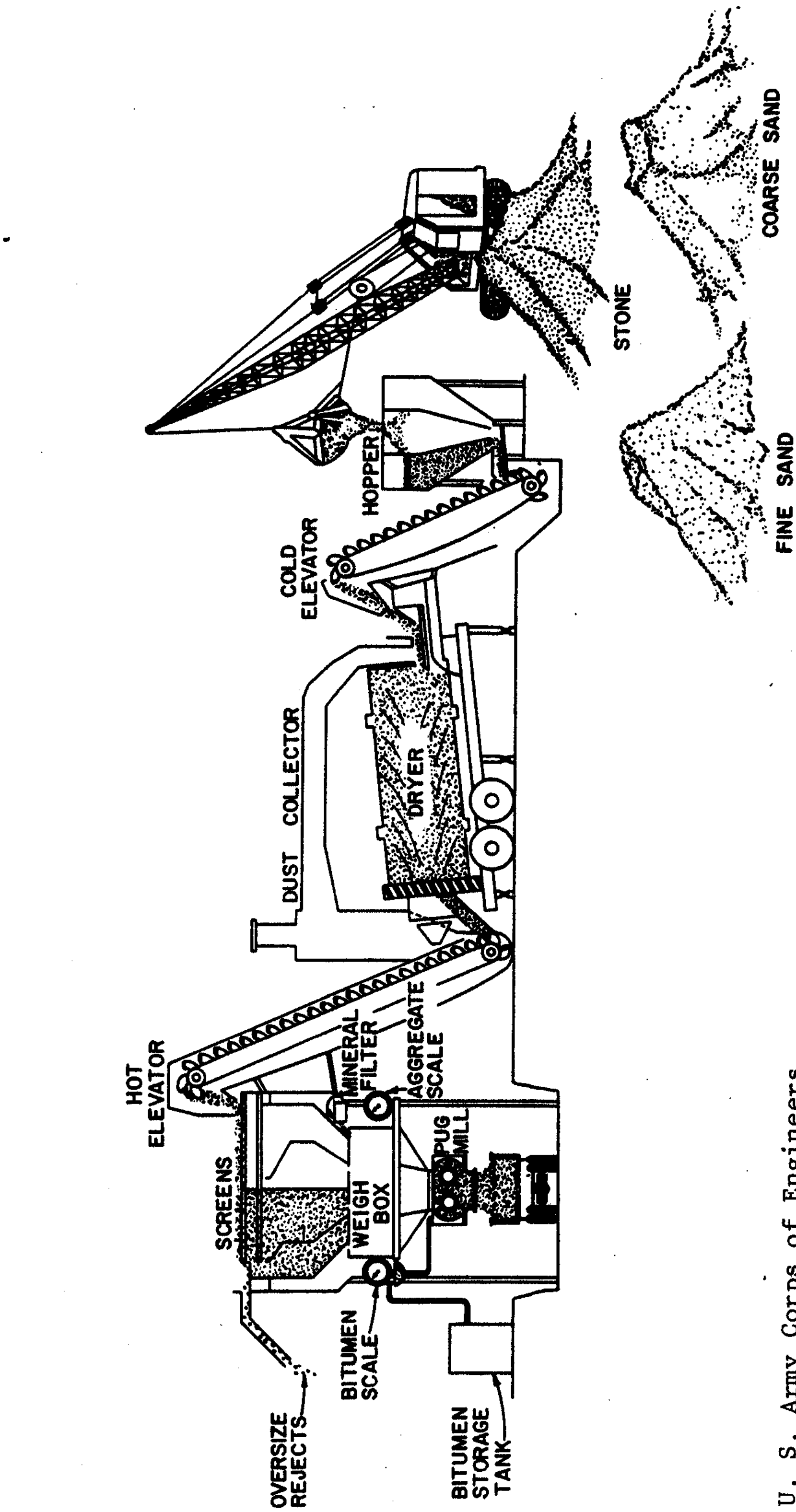

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FIGURE A-10. BATCH PLANT

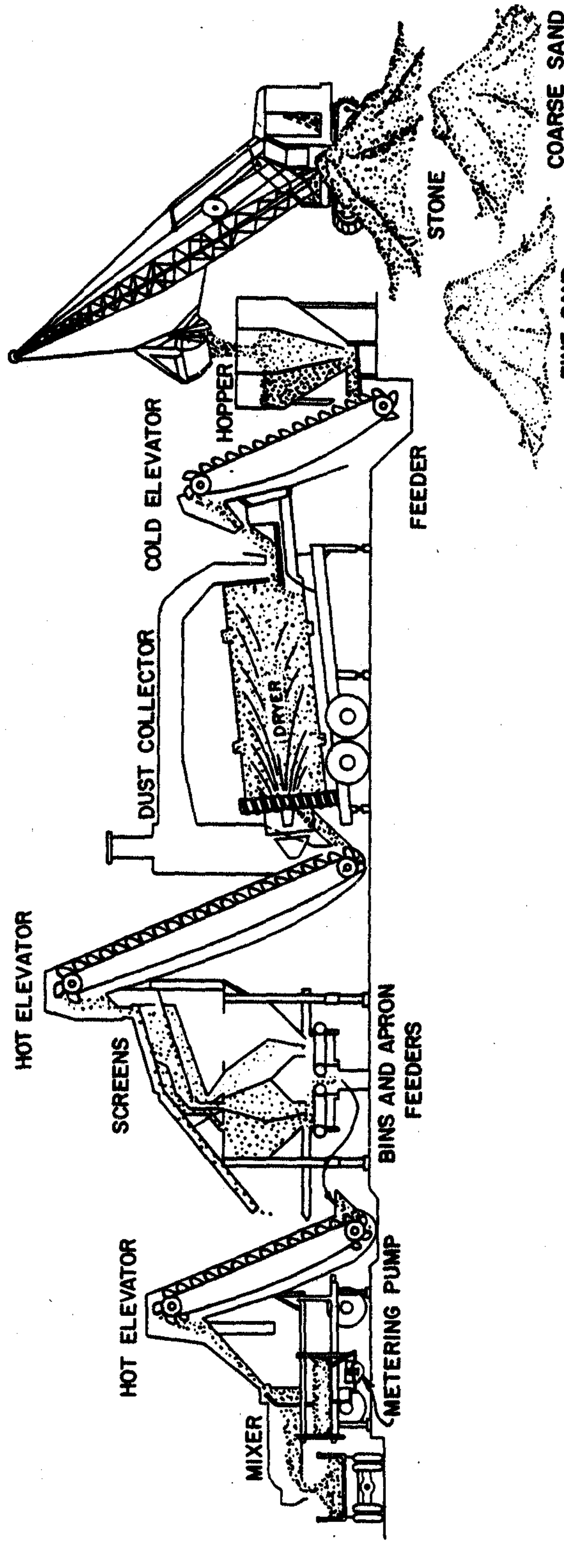

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FIGURE A-11. CONTINUOUS MIX PLANT

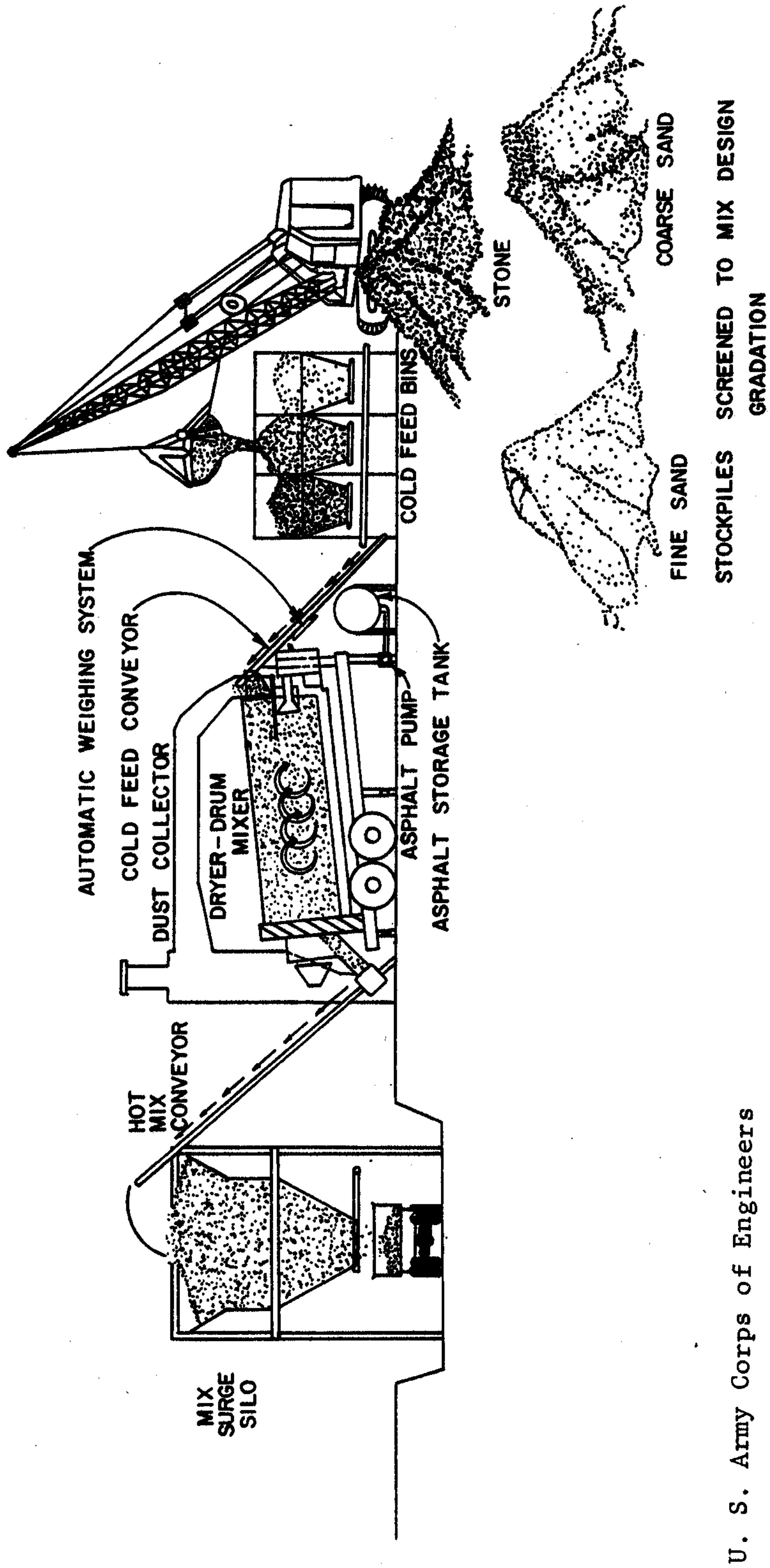

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FIGURE A-12. DRYER DRUM MIXING PLANT

two separate bins with the fine dried, the fine bin screen size should not be smaller than 3/8 inch. An additional screen is provided for further separation of the coarse aggregate in a four-bin plant. When additional mineral filler is required, usually it is stored and weighed or proportioned into the mix separately. Plant screens vary in size of opening, and the size employed is largely dependent upon the type of mixture being produced. In some cases, it may be necessary to change the size of screens to obtain a proper balance of aggregate sizes in each bin.

b. Adjustments to maintain proper proportions. The aggregates must be fed through the plant uniformly, preferably by a mechanical feeder, in order to obtain efficient plant operation and produce a mixture conforming to the desired gradation. The proper proportion of aggregates to be fed into the dryer may be determined approximately from the laboratory design. However, it is usually necessary to make some adjustments in these proportions because (a) a screen analysis of the stockpile aggregates generally will not entirely duplicate the screen analyis of the aggregate samples obtained for laboratory design use; (b) fines may be lost while passing through the dryer unless the equipment includes an effective dust collector; (c) aggregate may degrade in the dryer; and (d) the plant screens are not 100 percent efficient in separation of the aggregate and some fines are carried over into the coarser bins.

A3-2. Plant laboratory.

a. Equipment and personnel requirements. In order to control the plant output and secure the best possible paving mixture, a reasonably complete plant laboratory is necessary. The laboratory should be located at the plant site and should contain about the same equipment as is listed in Method 100 of MIL-STD-620. Due to the large capacity of most asphalt plants now in use, it is recommended that two technicians be assigned to conduct control tests; otherwise, the testing will fall too far behind, and considerable quantities of unsatisfactory mix could be produced and placed before the laboratory test results revealed that the mix is not in conformance with job specifications.

b. Laboratory work to initiate plant production. The heaviest demands on plant laboratory facilities arise at the initiation of plant production. Preliminary computations may be made to determine the weight of material from each bin that will provide the gradation on which the mixture design was based. However, it should be recognized that the gradation of the aggregate supplied by the plant in accordance with computed bin weights may not precisely reproduce the desired gradation. The gradation of the plant-produced aggregate generally approximates the gradation used in design, within reasonable tolerances, if initial sampling for design purposes has been accomplished properly and if the plant is operated efficiently.

Certain steps should be taken, however, to insure that satisfactory mixtures are produced from the beginning and throughout the period of plant production. Procedures subsequently outlined will insure satisfactory paving mixes.

c. Sieve analysis. All sieve analyses should be conducted in accordance with the appropriate ASTM procedures. Recommended sieves for plant sieve analysis are: 3/4- and 3/8-inch, Nos. 4, 8, 30, 100, and 200. Sieves larger than 3/4 inch should be used, if necessary. Sieve analysis should be made on material from each plant bin. Samples for these sieve analyses should be obtained after a few tons of aggregate have been processed through the dryer and screens in order that the sample will be representative. Final bin proportions may be determined on the basis of these analyses.

d. Provision for redesign of mix. The aggregates obtained from the bins (as described in the previous paragraph) sometimes cannot be proportioned to reproduce satisfactorily the gradation of the aggregate used in the laboratory design. It then is necessary to redesign the mix using plant-produced aggregates. Specimens are prepared and tested for the new design in the same manner as for the original design tests. Optimum bitumen content and probable satisfactoriness of the mix that will be produced by the plant are determined thereby. Occasions may arise where the gradation of the plant-produced aggregate will differ from that on which the laboratory design was based to the extent that a part of the aggregates must be wasted. Consideration should be given to redesigning the mix on the basis of additional tests of the plant-produced material in order to use all of the available aggregate. Sufficient additional tests should be performed to establish optimum bitumen requirements and ensure that the mix will meet applicable criteria for satisfactoriness.

e. Controlling plant production. A plant inspector should obtain a sample of paving mix from a truck as it leaves the plant after the plant has been in production about 30 minutes. The sample should be large enough to prepare four Marshall specimens and should be obtained by digging far enough into the load in several locations to obtain a representative sample of the paving mixture. The four specimens should be compacted and tested as rapidly as possible, in accordance with standard procedures cited previously. Plant production must be suspended until data from the tests are available and a determination made that the plant-produced mix conforms to final design data. If the test data on the plant mix show it to be within reasonable tolerances, plant production can be resumed; otherwise, necessary adjustments should be made to secure a conformable mix. Such procedures to insure initial production of satisfactory mixes will generally delay plant production less than 2 hours.

(1) Flow and stability. Resumption of plant production may be expedited by comparing only the values of flow, stability, and unit

weight of specimens compacted from plant-produced mixtures with corresponding data from the final design. Data from tests of the plant-produced mix for voids in the compacted mix and percent of voids filled with bitumen may be compared with corresponding design data after plant production has been resumed. When the plant is in continuous operation, the average flow and stability values obtained from truck samples should be in substantial agreement with flow and stability values from the final design. Variations of not more than two points in flow and not more than 10 percent in stability are allowable. In no case, however, will the plant-produced mix be considered acceptable if the flow or the stability does not meet the requirements of design criteria.

(2) Variations. If test property variations exceed those noted above, plant production should be delayed until the cause of the variations is determined. Computations for scale weights should be checked first. If no error is found in these computations, the plant proportioning equipment should be recalibrated. Variations of only a few tenths of 1 percent in bitumen content may cause variations of two or three points in the flow values. Small variations in aggregate weight generally are not particularly effective in changing test properties. Plant proportioning equipment found to be inaccurate should be adjusted and after an additional 30 minutes of plant operation, the paving mix should be sampled and tested; the plant will not be placed in continuous operation until the variations in test properties are within allowable tolerances. Once the plant has been placed in continuous operation, test specimens should be prepared for each 5-hours operation or fraction thereof. The tests conducted should include stability, flow, unit weight, voids in the total mix, and percent voids filled with bitumen. Normal variations in plant-produced aggregates will require minor adjustments in bin proportions, which will cause slight variations in test properties. Variations cited above are allowable for continuous plant production.

f. Significance of changes in mixture properties. A material increase in flow value generally indicates that either the gradation of the mix has changed sufficiently to require a revision in the optimum bitumen content for the mix, or too much bitumen is being incorporated in the mix. Substantial changes in stability or void content also may serve as an indication of these factors. As a general rule, however, the flow and stability values are obtainable quickly and are reasonably reliable indicators of the consistency of the plant-produced mix. The satisfactoriness of the plant produced mix may be judged quickly by maintaining close observance of the flow and stability values. Mix proportions must be adjusted whenever any of the test properties falls outside of the specified tolerances. In the case of batch plants, failure of the operator to weigh accurately the required proportions of materials or use of faulty scales are common causes for paving-mixture deficiencies. The total weight of each load of mixture produced should not vary more than plus or minus 2 percent from the total of the batch weights dumped into the truck. Improper weighing or faulty scales may be detected readily and corrective measures taken by maintaining close check of load weights. Other probable causes of paving-mixture deficiencies for both batch-and continuous-mixing plants are shown in figure A-13.

g. Other tests. In addition to the design and control tests described above, certain tests are desirable for record purposes and to insure quality and consistency of materials.

(1) Extraction tests. Representative samples of paving mixture should be obtained twice daily for extraction tests to determine the percentage of bitumen in the mix and the gradation of the extracted aggregates. Extraction tests are to be made in accordance with ASTM D 2172 using trichloroethylene as the extraction solvent. Sieve analyses of recovered aggregates should be in accordance with procedures specified previously.

(2) Hot-bin gradations. Hot-bin gradation tests should be determined on the aggregate in the fine bin at 2-hour intervals during operation. Hot-bin gradations must be determined on all bins in conjunction with sampling of the pavement mixture. Washed sieve analyses are to be determined initially and when gradations vary to establish a correction factor to be applied to unwashed (dry) gradation. Dry sieve analyses should be conducted frequently as required to maintain control.

h. Construction control. It has been determined that well-designed mixes can be compacted readily by adequate field rolling to about 98 percent or greater of the density obtained by compacting specimens with previously specified laboratory procedures. Every reasonable effort is to be made, within practicable limits, to provide an in-place pavement density of at least 98 percent of the compacted density as determined by the laboratory tests. Bituminous intermediate or base course mixes are to be rolled to the density specified in applicable Corps of Engineers guide specifications.

(1) Pavement sampling. Samples for determining pavement density and thickness may be taken either with a coring machine or by cutting out a section of pavement at least 4 inches square with a concrete saw and should include the entire thickness of the pavement. A set of the samples will be taken from areas containing mix that was previously sampled from trucks and from which specimens were compacted in the plant laboratory. A set of samples will consist of at least three sawed or cored samples. Density samples of each day's production should be taken and delivered to the project laboratory by noon of the following day, and the density determinations made by the end of that day. This will permit any changes in placing technique necessary to obtain the required density to be made before too much pavement is placed. One-half the total number of all density samples will be taken

Types Of Hot Mix Trouble

Probable Causes Of Deficiencies In Hot Plant Mix Paving Mixtures \ Types Of Deficiencies That May Be Encountered In Producing Hot Plant Mix Paving Mixtures	Bitumen content fails to check job-mix formula	Gradation fails to check job-mix formula	Poorly mixed loads	Fat, rich mixtures	lean or burned mixtures	Mixture temperature fails to check job mix	Smoking loads	Steaming loads	Overweight or underweight loads	Lack of uniformity of mixtures in loads
1 Aggregate scales out of adjustment	X	X		X	X					
2 Bridging of hot aggregate in bin		X							X	X
3 Bitumem scales out of adjustment	X			X	X				X	X
4 Lack of proper weighing by operator	X	X		X	X				X	X
5 Faulty pug mill dump gate	X	X	X	X	X				X	X
6 Bitumen temperature too high			X	X	X	X				X
7 Drum feed not uniform						X	X	X		
8 Improper dryer operation					X	X	X	X		
9 Too little bitumen	X				X					X
10 Too much bitumen	X			X						X
11 Sampling method not uniform	X	X		X	X					
12 Excessive moisture content of aggregate								X		X
13 Bin overflow pipes not functioning	X	X								X
14 Leaky bins	X	X		X	X					X
15 Segregation of aggregates in bins		X								X
16 Mixing time not uniform	/		X							X
17 Mineral filler feed not uniform	X	X		X						X
18 Aggregate temperature too high					X	X	X			
19 Temperature mechanism out of adjustment					X	X	X	X	X	X
20 Improper feed of aggregates to dryer	X	X		X	X		X	X		X
21 Overrated dryer capacity						X		X		X
22 Faulty screen operation										X
23 Overload pug mill			X							X
24 Improper set on pug mill	X	X	X							X
25 Bitumen and aggregate feed out of adjustment	X	X		X	X					X
26 Bitumen pump not functioning properly	X			X	X					
27 Not sufficient hot aggregate in storage bins	X	X								X
28 Aggregate gates not properly set	X	X		X	X					X

Items 6 to 23 incl. are applicable to all types of plants. Items 1 to 5 incl. and items 24 to 28 incl. are applicable to batch plants and volumetric plants respectively.

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FIGURE A-13. TYPES OF HOT PLANT MIX PAVING MIXTURE DEFICIENCIES AND PROBABLE CAUSES at a joint so that the joint is approximately in the center of the sample to be tested.

(2) Testing pavement samples. Pavement samples are to be prepared for testing by carefully removing all particles of base material or other matter. All broken or damaged edges of sawed samples for density tests will be carefully trimmed from the sample. Thickness measurements are to be made prior to splitting. A sample consisting of an intermediate course and surface course will be split at the interface of these layers prior to testing. The density of the sawed samples then will be determined by weighing in air and in water as previously described. Samples from which density measurements are desired should be discarded if they are damaged.

(3) Density data. Density data obtained from specimens in the manner previously described will be compared to the laboratory densities that have been determined from the sample plant-mix material previously taken from loaded trucks.

i. Pavement imperfections and probable causes. There are many types of pavement imperfections resulting from improper laying and rolling operations as well as from improper mixes or faulty plant operation. These imperfections can be controlled only by proper inspection. Pavement imperfections that may result from laying improper mixes or using faulty construction procedures are shown in figure A-14.

Probable Causes of Imperfections in Finished Pavements \ Types of Pavement Imperfections That may be Encountered in Laying Hot Plant Mix Paving Mixtures	Bleeding	Brown, dead appearance	Poor surface texture	Rough uneven surface	Uneven joints	Roller marks	Shoving	Waves	Cracking	Honeycomb	Tearing of surface during laying
Excessive moisture in mixture		X					X				
Not cut back to uniform thickness					X						
Inadequate cross rolling				X		X					
Excess of bitumen in mixture	X						X				
Lack of bitumen in mixture		X							X		X
Mixture too coarse	X		X						X	X	
Roller standing on hot pavement				X				X			
Faulty allowance for compaction					X						
Unstable basecourse				X				X			
Poorly graded mixture	X		X				X		X		
Rolling mixture when too cold				X	X	X			X		
Rolling mixture when too hot				X			X	X			
Mixture too cold				X	X		X	X	X	X	X
Mixture too hot or burned		X					X				
Poor spreader operation				X	X			X		X	X
Inadequate rolling				X		X					
Excessive segregation in laying	X		X	X					X	X	
Poor handwork behind spreader				X	X			X		X	
Unsatisfactory batches in load	X		X	X			X		X	X	X
Improper proportioning	X		X	X			X		X	X	
Excessive primecoat	X										

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FIGURE A-14. TYPES OF HOT PLANT MIX PAVEMENT IMPERFECTIONS AND PROBABLE CAUSES